

MILLIMETER RADIOMETER SYSTEM  
TECHNOLOGY

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JPL has had a large amount of experience with spaceborne microwave/millimeter-wave radiometers for remote sensing. This has included the Microwave Sounder Units (MSU) at 50-60 GHz, for Nimbus temperature sounding, the Scanning Multichannel Microwave Radiometers (SMMR) (6-37 GHz) for Nimbus G, SeaSat and currently TOPEX, and the Upper Atmospheric Research Satellite (UARS) Microwave Limb Sounder (MLS) with frequencies between 63 and 205 GHz. Future plans include an EOS\* MLS for atmospheric measurements from 63 to 650 GHz, the Scout for interstellar oxygen and water vapor measurements from 60-550 GHz and the Submillimeter Explorer for astrophysical observation from 500-3000 GHz. In the long term we are planning the Large Deployable Reflector for astronomy in the 500-10,000 GHz frequency range. All of these instruments use filled aperture antenna systems from 5 cm diameter for the MSU, 1.6 m for the MLS to 20 m for LDR.

The advantages of filled aperture antenna systems are shown in Figure 1 below. For frequencies above 30 GHz, filled aperture antennas can provide the required footprints. A 10-m diameter deployable filled aperture millimeter-wave antenna could be made today with only limited development. The inner portion of this antenna could be made precise enough for operation to 183 GHz. In the future, a larger millimeter-wave antenna could be assembled at the Space Station and then sent up to geosynchronous orbit.

\*Earth Observing System (EOS).

## **FILLED APERTURE ANTENNA SYSTEMS**

- SIMPLE CONCEPT - PREVIOUS EXPERIENCE
  - DEPLOYABLE - 10m AT TRW
  - SPACE STATION ASSEMBLY - 30m BASED ON LDR TECHNOLOGY
- MULTIPLE FREQUENCIES
- FEED ARRAY WITH MULTIPLE RECEIVERS
- ACCURATE MEASUREMENTS
  - HIGH BEAM EFFICIENCY - 90-95%
  - LOW SIDE LOBES - <25 dB
- DATA PROCESSING STRAIGHTFORWARD

Figure 1

The footprint size (3 dB antenna beamwidth) at nadir vs antenna diameter and frequency are shown in Figure 2. To achieve a 20-km footprint at 183 GHz, a 4-m diameter antenna with a beamwidth of 1.7 arcmin will be required.

## FOOTPRINT vs ANTENNA DIAMETER

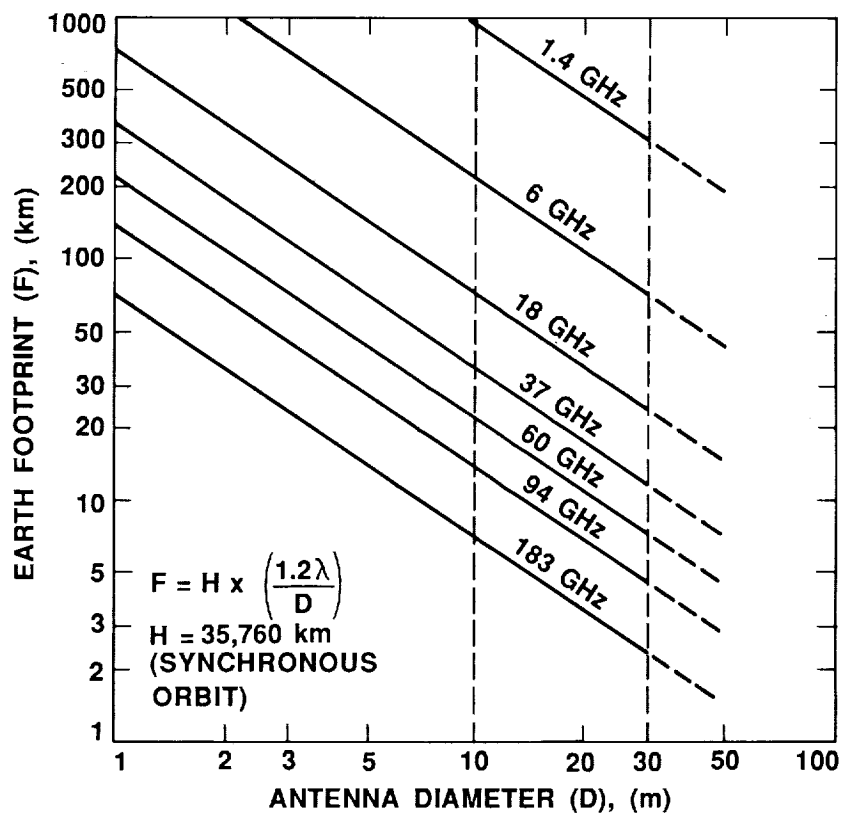


Figure 2

In Figure 3, the diameter requirements for a possible Geoplat antenna system are shown and are compared against existing ground based and proposed space telescopes. As seen, the technology required for a 10- to 30-m Geoplat antenna is well within the state of the art for a ground-based antenna. The challenge is to make this antenna in space.

## DIAMETER vs OPERATING WAVELENGTH FOR VARIOUS CLASSES OF TELESCOPES

- |    |                       |    |                  |
|----|-----------------------|----|------------------|
| 1  | U. TEXAS              | 9  | IRAM 15m         |
| 2  | OVRO 10m              |    | SRC 15m          |
| 2A | CIT SUBMM OBSERVATORY | 10 | MPIFR/IRAM 30m   |
| 3  | NRAO 11m              | 11 | SIRTF            |
| 4  | CRIMEA                | 12 | SPACE TELESCOPE  |
| 5  | NRAO VLA              | 13 | HALE 200"        |
| 6  | OVRO 40m              | 14 | U. OF TEXAS 300" |
| 7  | BONN 100m             | 15 | KECK TELESCOPE   |
| 8  | NASA DSN 64m          |    |                  |

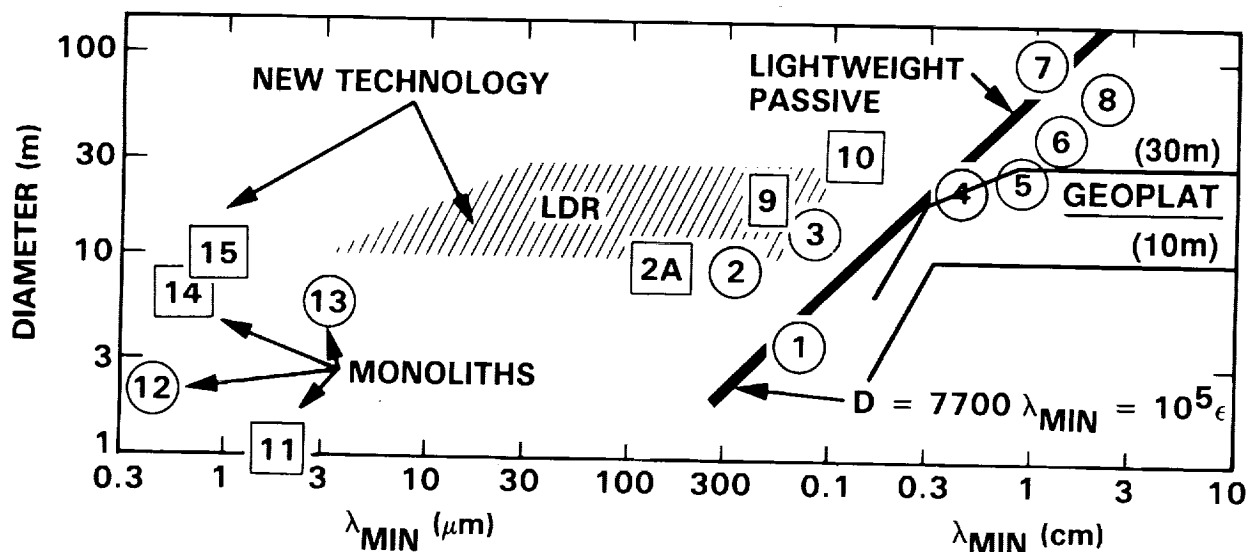


Figure 3

Figure 4 shows a number of proposed reflectors for space, with the type of construction indicated. For the 10-m Geoplat antenna, a passive precision deployable antenna could be built to satisfy the requirements.

## REFLECTORS FOR SPACE

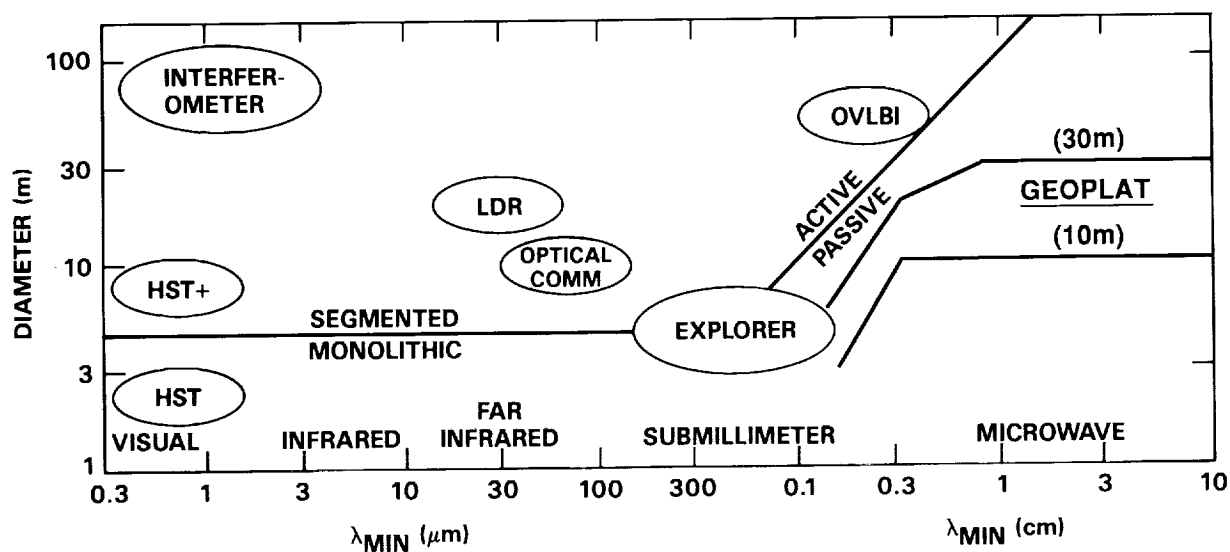
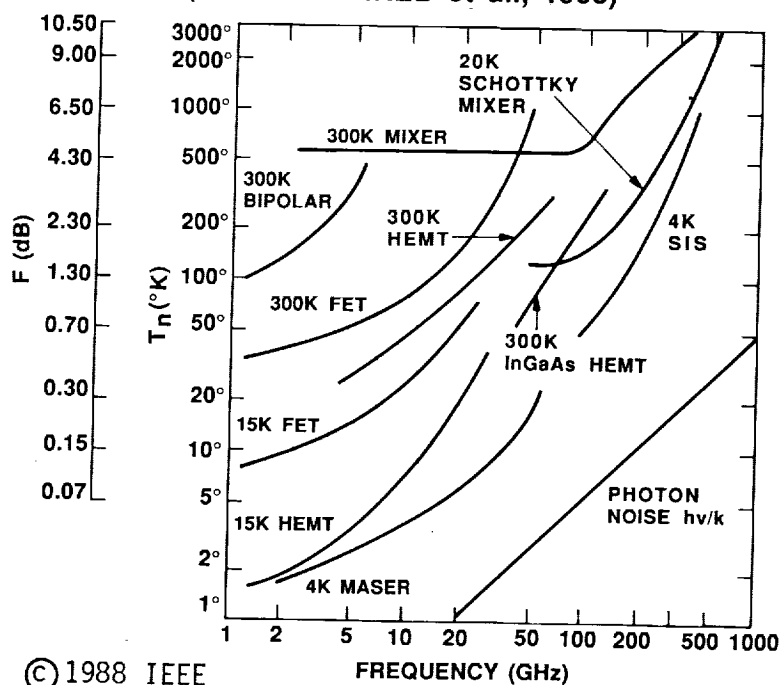


Figure 4

The current state of the art of receiver noise performance vs. frequency is shown in Figure 5. These data are from Weinreb, et. al., (ref. 1) with additional data on the new Hughes InGaAs HEMT\* (ref. 2) added. For remote sensing of the Earth, a radiometer noise temperature  $<100$  K would be adequate. Thus, for frequencies below 120 GHz, it is now possible to use HEMT amplifiers as the first radiometer stage. At 183 GHz it would be necessary to use a cooled Schottky mixer radiometer. For continuum receivers it is possible to have IF bandwidths of 10-25% of the center frequency. Each receiver channel will require 5-15 watts of DC power.

\*High electron mobility transistor (HEMT).

### STATE-OF-THE-ART OF NOISE PERFORMANCE FOR MICROWAVE/MM-WAVE DEVICES - 1988 (FROM WEINREB et al., 1988)



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Figure 5

A calculation of the performance for a possible radiometer system using a 10-m diameter antenna, scanning a 4,000-km diameter area within 0.5 hr. is shown in Figure 6. This system calculation assumed a multifeed system making a raster scan across the area of interest. The scan rate would be 11 degrees/minute. To reduce this scan rate, the number of receivers could be increased to increase the swath width or the revisit time increased. The technical parameters which can be traded off in this system design are the area scanned, time of the scan, scan width (number of receivers), and the rms noise ( $\Delta T$ ). With the proper momentum compensation it should be possible to mechanically scan a 100-150 kg antenna system at these low scan rates.

Some technical areas that will require development for a Geostationary platform are:

- (1) 10-m diameter deployable antenna operating to 100 GHz with the inner 4-m diameter operating to 183 GHz
- (2) HEMT amplifiers operating to 118 GHz
- (3) 4-6 element array feed systems for mm-wave antennas.

## 10- m MULTIFEED ANTENNA - SENSITIVITY AND SCANNING

FREQ (GHz)	F* (km)	Nrec	$\tau$ (ms)	Tsys** (K)	$\Delta T$ (K)
18	83	1	1588	344	0.01
37	40	2	376	355	0.01
60	25	4	143	451	0.12
95	16	6	57	586	0.04
118 #	20	5	92	698	0.23
183 #	20	5	92	887	0.29

AREA DIAMETER = 4000 km

SCAN TIME = 0.5 hr

SCAN RATE = 11 deg/min

\* FOOTPRINT AT 30 deg LATITUDE

\*\* T(BACKGROUND) = 270 K

# REDUCED ANTENNA SIZE USED

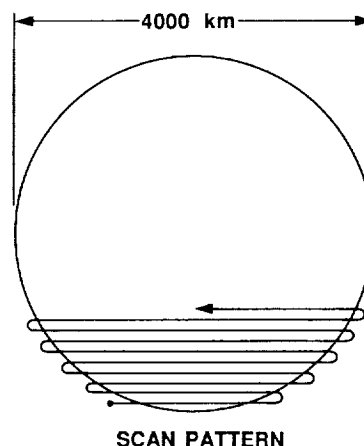
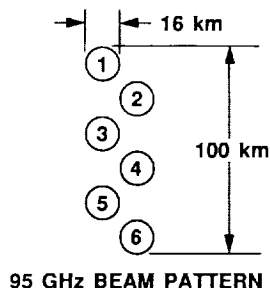


Figure 6

A description of the application of Microwave Limb Sounding is shown in Figure 7 along with the advantages of Geostationary observations.

## MICROWAVE LIMB SOUNDING

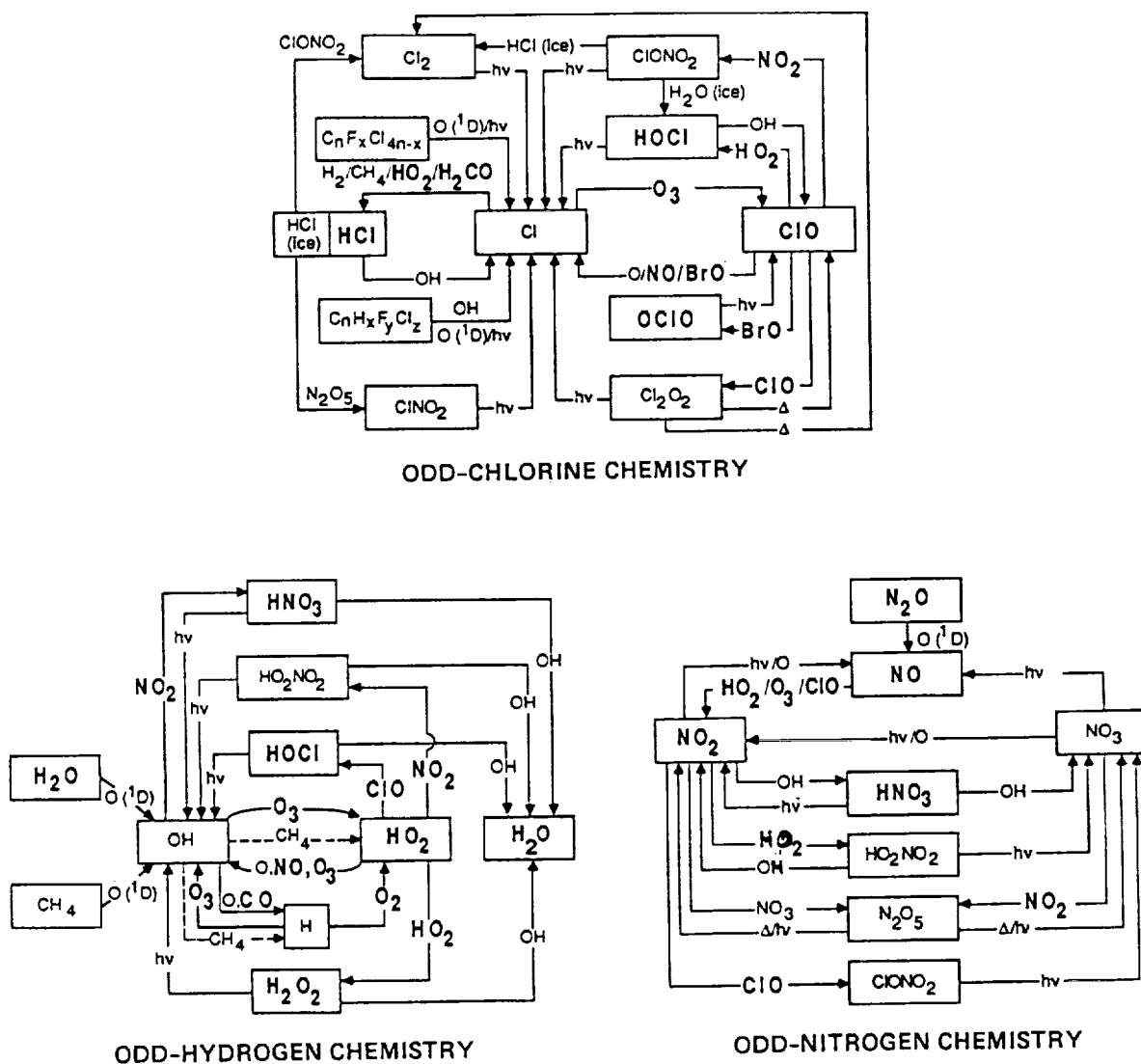
- Performs measurements for monitoring depletion of stratospheric ozone
  - Measures key molecules in all known O<sub>3</sub> destruction cycles
  - Unique capability for measuring chemical radicals which control rate of O<sub>3</sub> destruction
  - Especially strong for monitoring depletion of O<sub>3</sub> by industrial chlorocarbons, and the Antarctic Ozone Hole
  - Measurements are of thermal emission and can be made any time of day or night
- Low Earth orbit experiments have been developed
  - MLS on the Upper Atmosphere Research Satellite
  - Enhanced MLS proposed for Eos
- Geostationary platform advantages
  - Optimization of latitude coverage between  $\pm 81$  degrees
  - Detailed study of time variation at specific latitude bands
- Measurement capability and antenna size requirements

Figure 7



The key molecules for stratospheric ozone chemistry, can be measured with a Microwave Limb Sounder, and are shown in Figure 8.

## MICROWAVE LIMB SOUNDING

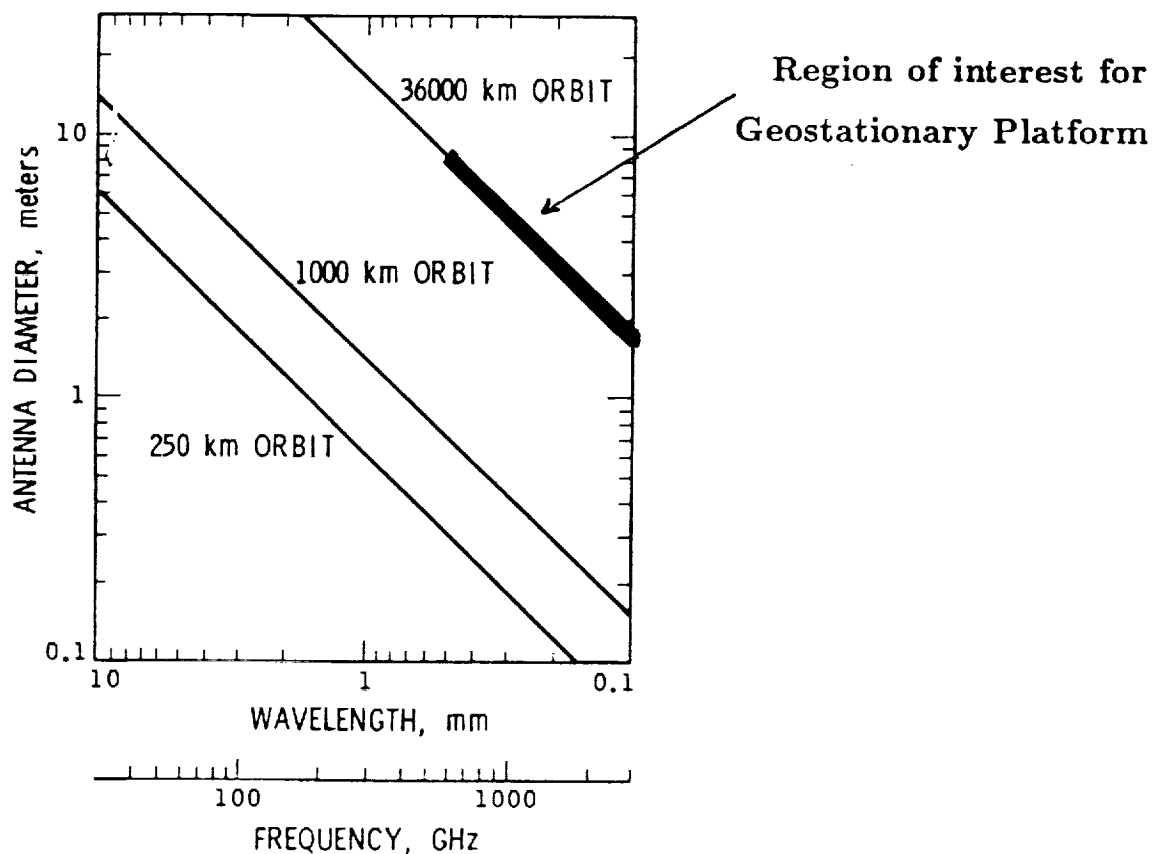


**Stratospheric Ozone Chemistry Schematics and Microwave Limb Sounding Measurements.** Microwave limb sounding measurements which can be made by existing 600 GHz technology are shown in larger type. Technology advances to 2000 GHz will allow additional important measurements of OH and atomic O

Figure 8

The antenna requirements for a Submillimeter Limb Sounder are shown in Figure 9. For receivers in the 600-1200 GHz frequency range, antenna diameters of 3-8 m would be desirable.

## MICROWAVE LIMB SOUNDING



ANTENNA DIAMETER FOR 3 km BEAMWIDTH AT  
TANGENT POINT FOR LIMB OBSERVATIONS

Figure 9

## REFERENCES

1. Weinreb, S., Pospieszalski, M. W., and Norrod, R., "Cryogenic, HEMT, Low-Noise Receivers for 1.3 to 43 GHz Range," IEEE Microwave Theory & Techniques Symposium Digest, June 1988.
2. Greiling, P. T., "Low Noise HEMT Amplifier at 60 GHz," IEEE Device Research Conference, Boulder, Colorado, June 1988.

